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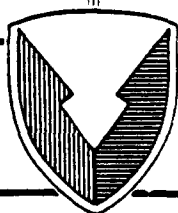


DESIGN AND DEVELOPMENT OF MINILINK VIDEO: A FIBER-OPTIC COUPLED VIDEO SYSTEM

Darryl Holder
Weapon Sciences Directorate
Research, Development, and Engineering Center

FEBRUARY 1992

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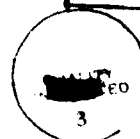
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<p>This report documents the in-house design, construction, and testing of a battery powered video camera which transmits its signal along a fiber-optic cable to the monitoring station. Certain types of testing require that a video camera be placed in close proximity to the test article, which results in the camera being subjected to the full force of the test environment, which often impairs its performance or causes it to fail entirely. In commercially available units, power and video cables which connect to the camera pose an electric shock hazard in some tests and can be a source of unwanted pickup of electromagnetic fields. The necessity for in-house design of this system was realized after a survey showed that no one manufacturer offers a system meeting all of the requirements for video monitoring. Because of these factors, a battery powered video camera which transmits its signal along a fiber-optic cable to the monitoring station has been designed in-house. The experimental version of this camera has proven to have substantial advantages over the previously used cameras. In actual monitoring tests, the camera proved to be resistant to the environment, provided better contrast, higher resolution, and greater capability of operation at low light levels. This unit was successful for its intended purpose, and is a generally useful device with no changes. Future plans are to further extend the experimental design of the system to allow test monitoring with greater efficiency while yielding superior images.</p>				
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I. INTRODUCTION

Certain types of testing require that a video camera be placed in close proximity to the test article. In this position the camera is subjected to the full force of the test environment and often its performance is impaired or it fails entirely. Power and video cables which connect to the camera may also present a problem. These cables pose an electric shock hazard in some tests and can be a source of unwanted pickup of electromagnetic fields. Because of these factors, a battery powered video camera that would transmit its signal along a fiber-optic cable to the monitoring station was designed. The camera is controlled by an optic signal transmitted on the return path along the fiber-optic cable.

II. DESIGN

A survey was made of the equipment and systems available for video monitoring. The survey showed that, while there were several systems that came close, no one system met all of the requirements. During this survey a low power consumption charge-coupled device (CCD) camera module was found. This CCD camera module was designed for original equipment manufacturers and as such, was particularly suited for application to a specialized design. The module was available in several configurations; the one chosen was Phillips Components part number 56471 which has the following abbreviated specifications:

- Sensor - Black and white imaging CCD with zero pixel defects
- Resolution - 610 by 492 pixels
- Sensitivity - 0.02 lux
- Output - NTSC standard composite video signal
- Power - 12 volts DC at 165 milliamps
- Size - 2.0 in. wide by 1.5 in. high by 3.5 in. long.

In addition to the camera module there must be a power supply and control system, provisions for reception of fiber-optic control signals, and fiber-optic transmission of the video signal.

The power supply and control system consists of a rechargeable battery pack, a regulated power converter, and a circuit which receives the fiber-optic control signals and turns the camera power on and off. A set of four, size "F", 7.0 amp-hour, nickel-cadmium cells were selected for the battery pack to provide ample running time. In order to boost the nominal five volts output of this battery pack to the required 12 volts, a DC-to-DC converter was used. The converter selected was a Pico Electronics model number LRE12S. This is a solid state module 1.9 in. long by 1.8 in. wide by 0.5 in. high, which provides 12 volts DC at 333 milliamps with a 1.25 % regulation over the input range of 5 to 15 volts input. This module also has a control pin which, when connected to the negative input (grounded), will shut down the module and thus remove power to the camera module. A fiber-optic interfaced PIN photodiode (Hewlett-Packard # HFBR-2208) and a CMOS gate, form a simple receiver to provide power on/off control. Transmission of the video signal

to the receiving station is accomplished by the use of an OEM fiber-optic video transmitter module. This transmitter (Math Associates model XV-1050) is a module measuring one inch square and a half-inch thick with an SMA fiber-optic connector on one square face and electrical connections on the other. There are three electrical connections: common (ground), power (+12 volts DC at 40 milliamps), and the video input (1 Volt peak-to-peak into 75 ohm termination). The XV-1050 is self-contained and requires no adjustments.

Figure 1 is a schematic of the video camera electronics excluding the battery pack and the CCD camera module itself. The circuitry is divided among two circular circuit boards and a circular aluminum plate which serves as the rear bulkhead of the shielding camera case. On this rear bulkhead are mounted the fiber-optic video transmitter module (TX1), the fiber-optic control receiver diode (RX1), the power switch (S1), the sync mode switch (S2), and the battery charging jack (JØ). The power switch changes between the Operate state (where the fiber-optic control receiver is operating to control the DC-to-DC converter) to the Off/Charge state (where the battery pack is disconnected from the circuit and may be charged). The sync mode switch will, when implemented, provide for the selection of internal sync or external sync of the video camera module. For expediency, it is not implemented here. Flexible wires connect between these components and the circuitry on the I/O Board.

On the I/O Board, JP1 is a jumper plug set which is used to set up fixed operation modes of the camera. By means of shorting the appropriate adjacent pins, progressive or interlaced scan, and a gamma correction of 1 or 0.45 can be selected. If the camera is to be used with a computer interface (frame-grabber card) it would likely be set for progressive scan and gamma = 1. If it is to be viewed on a monitor or recorded, then interlaced scan and a gamma = 0.45 (which compensates for picture tube distortions) would most probably be used. Also on JP1 is an option for power supply source. If the camera is required to operate for extended periods of time and the direct connection of an external power supply is possible, then a jumper can be changed which will disconnect the battery pack and permit a DC power source of between five and ten volts to be applied via JØ. Also on the I/O board is the control receiver electronics. For this implementation, the receiver consists of a single CMOS Schmitt-trigger NAND gate (CD4093B). The extremely high input impedance of the CMOS chip and the snap-action and hysteresis of the Schmitt-trigger provide an effective and inexpensive amplifier for the PIN photodiode in RX1. When light is transmitted into RX1, the PIN photodiode conducts, causing a voltage drop across its bias resistor (R1). This voltage drop transitions the logical 1-to-Ø hysteresis level of the gate and the output level snaps from logical Ø to 1 (current-sinking low state to the high state). This signal is used to turn on the DC-to-DC converter. The other three channels of NAND in this chip are disabled here, but will be used in future versions to permit demultiplexing a sync signal from the fiber-optic control input signal.

The power and distribution board holds the DC-to-DC converter and associated circuitry, and provides for the distribution and routing of the various signal and

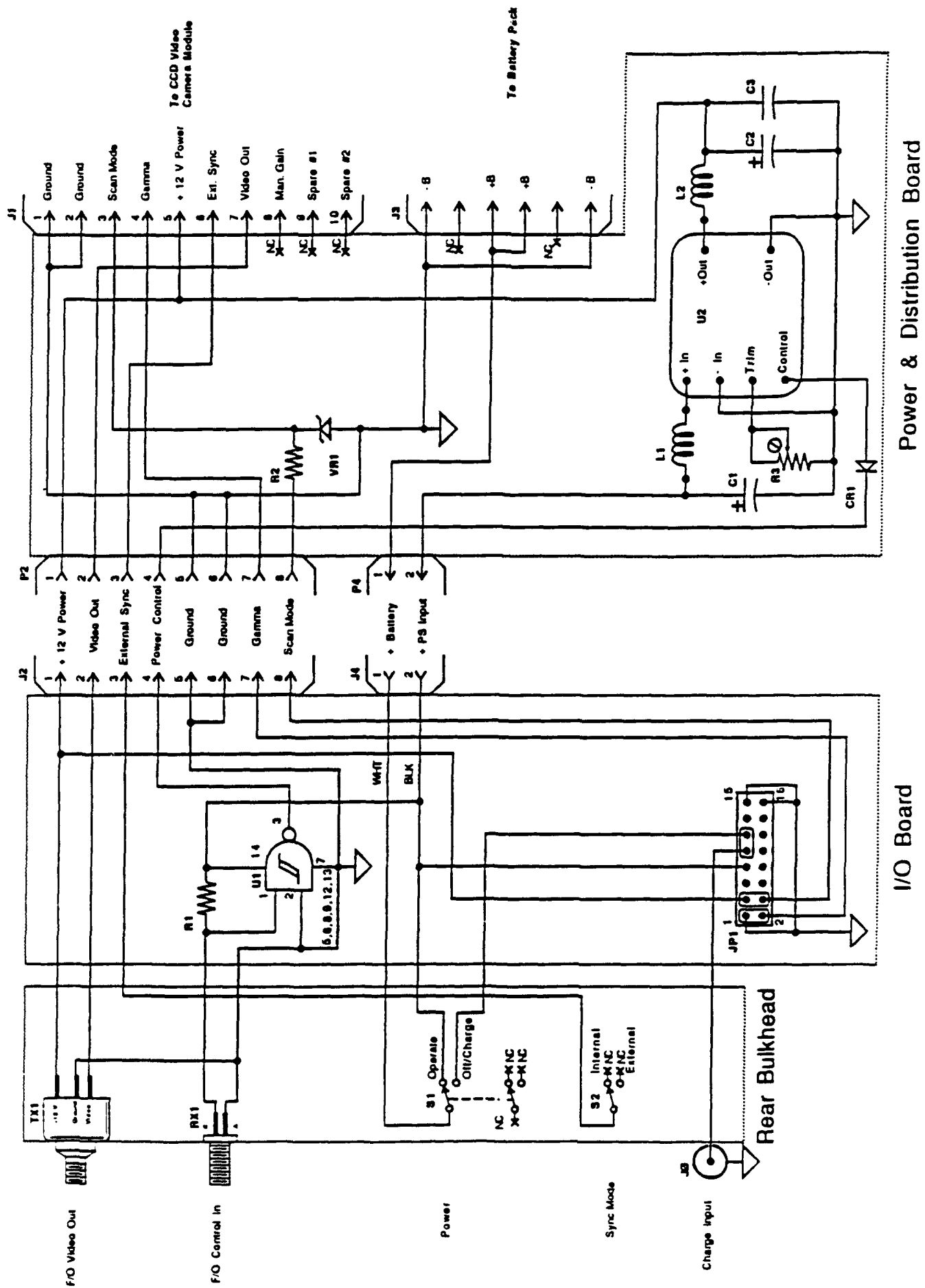


Figure 1. Video camera electronic schematic diagram.

power connections. The LRE12S DC-to-DC converter has inductors (L1, L2) and capacitors (C2, C3, C4) connected to its +In and +Out pins which serve to isolate its internal chopper noise from the sensitive electronics of the CCD camera module. A trimpot (R2) is connected to the trim pin to provide precise adjustment of the +12 Volt output. The anode of a signal diode (CR1) is connected to the control pin. This provides for power down of the DC-to-DC converter via current-sinking by the NAND chip on the I/O Board, but prevents that chip from driving current into the control circuitry which would upset its operation. Finally, a resistor (R1) and a Zener diode (VR1) provide +5 volts to enable the scan mode selected. For the distribution functions, a fly-lead, 8-wire ribbon cable connector (P2) mates with J2 of the I/O Board for transfer of signals and regulated +12 volt power. Likewise, a two-wire cable connector (P4) mates with J4 of the I/O board to provide the positive battery pack output to S1 for control of the returned positive voltage input to the DC-to-DC converter. A 10 circuit header connector (J1) provides power and control to, and video signal from, the CCD camera module. Finally, a six position pin strip connector provides for connection of the battery pack.

III. CONSTRUCTION

Figure 2 shows a physical layout of the major parts of the camera in its environmental case. The components for this prototype were modelled using a 3D drawing package (Super 3D by Silicon Beach Software) on a Macintosh computer. Using these representations, a package design was quickly obtained by manipulating these images on the computer's screen. The image shown in Figure 2 is a slightly simplified version of the final 3D representation. As was done for the figure, images of the more complex portions of the design (such as the front bezel) were exported to a drafting package (MacDraft by Innovative Data Design) and were used to produce shop drawings for production of the various casework parts. A full collection of the shop drawings is shown in the Appendix.

The case for the camera was fabricated from aluminum pipe. This stock has an outside diameter of 4.00 inches and an inside diameter of 3.50 inches. The wall dimension was chosen this thick to allow for coarse threads to be cut for the attachment of the front bezel and the rear securing ring. A case this thick also provides ample physical protection. The rear bulkhead is fabricated from 0.0625 aluminum sheet.

Since the CCD camera module has no case, a pair of punched and folded sheet aluminum brackets was fabricated to enclose the unit and provide for its attachment to Bulkhead #1, the module's rear support and electrical interface board. For this prototype, Bulkhead #1 was made from perforated epoxy-glass electronic prototyping board. An 8-contact Mini-DIN male plug connects the CCD camera module to a 10-pin male header connector on the bulkhead — the two extra pins being designated as spares. A 10-pin ribbon cable connects from this header connector to another such connector (J1) on the power & distribution board.

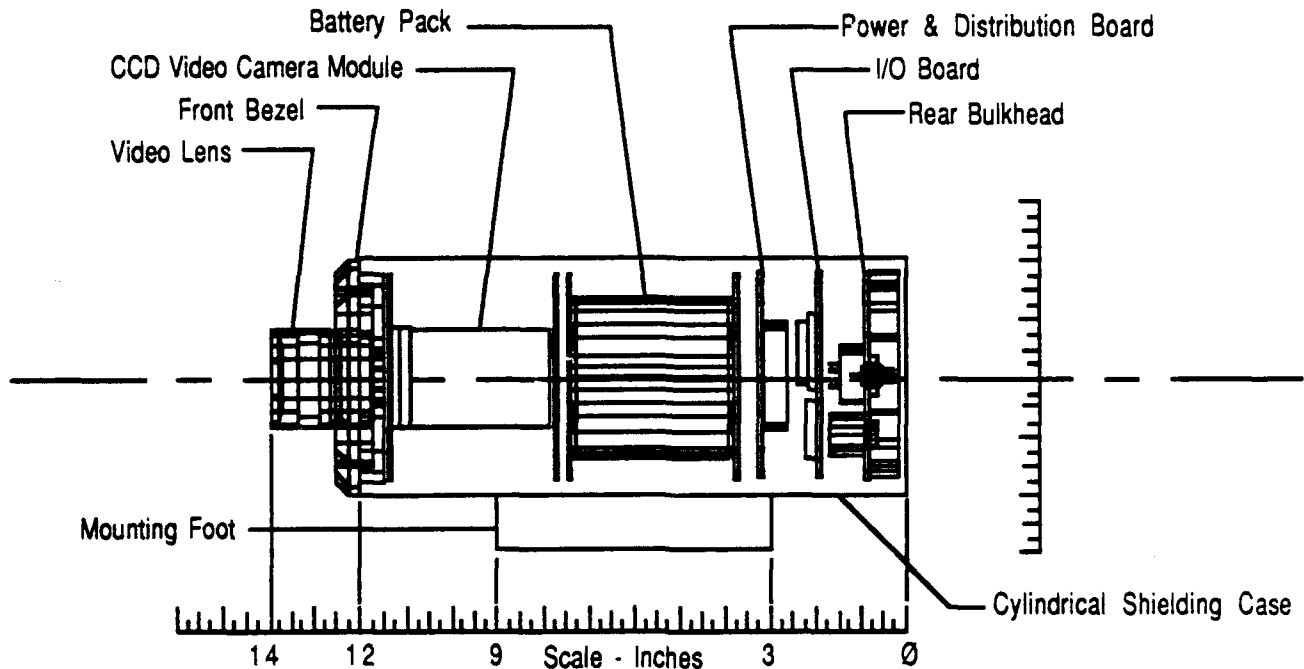


Figure 2. Video camera physical layout.

As shown in Figure 1, all of the camera's electronics except for the CCD camera module itself is on the power & distribution board, the I/O Board, and the rear bulkhead. Of these, the first two are made from perforated epoxy-glass, as was Bulkhead #1. Since this was a one-off experimental and evaluation unit, these boards were hand-wired so that changes could readily be made. These two boards, the rear bulkhead, and a bracket for the support of the battery pack were fastened together in a stack using standoff spacers. This whole unit, including the battery pack, is inserted into the case from the rear until the rear bulkhead seats in the rear cavity of the case. The securing ring is then screwed into the environmental case to seal it; a small locating pin prevents the rear bulkhead from turning as the securing ring is screwed tight. The mounting foot (shown in the Appendix) provides for attachment to standard camera supports such as tripods. This was attached to the case using stainless steel straps.

For the camera to be useful, it must have a receiver and control station. For this experimental and evaluation effort, a simple design consisting of a Math Associates FR-1000 fiber-optic video receiver and a fiber-optic interfaced LED was used. The FR-1000 receives the video signal through the optic fiber cable and translates it to NTSC standard composite video which is routed to a video monitor and a video cassette recorder. The fiber-optic interfaced LED is a Hewlett-Packard

HFBR-1402 and is connected in series with a toggle switch and a resistor which is attached to a 5-volt power supply. When closed, the switch causes the LED to light and project its energy into the optic fiber cable and thus to the RX1 receiver PIN photodiode in the video camera. This causes the camera to start functioning. The optic fiber cable is a 100-meter long duplex cable assembly. This cable has two separate fibers (100 micron core, 125 micron cladding) in a "zipcord" jacket. Although the two signals could be sent on a single fiber, the transmitter and receiver units for this are not readily available and the duplex cable presents no more problems than would a single fiber cable.

IV. TESTING

Testing of the various components of the system was carried out during development of the circuitry. Of first concern is the power drain at the "alert" condition — the state where the camera is in the Operate mode, but is not being commanded to function. The power consumed by the RX1, U1 circuit from the + battery line for this condition is about 10 μ amps, as expected. The current drawn from the control pin (logical zero current sinking) of the LRE12S DC-to-DC power supply however, is in the range of a milliamp or so — higher than desired, but not unacceptable if the camera is manually switched to the Off/Charge mode during longer breaks in operation. The sum of the input currents of the CCD camera module and the TX1 fiber-optic video transmitter is 205 milliamps at 12 volts. For testing purposes, and to allow margin for circuit growth, the full load current required at 12 volts is specified as 230 milliamps. The input current to the LRE12S DC-to-DC power supply at 5.00 volts input and the output voltage trimmed to 12.00 volts is 805 milliamps. This amounts to a 68% efficiency of conversion. Since the efficiency of the converter is specified at full load (79% at 333 milliamps for this model) if the productive power requirements of the camera circuitry increase (such as the use of a color camera module or the addition of more sophisticated control circuit operations) then a smaller portion of the power should be lost in the conversion and regulation process.

Variation of the +12 volt output over the expected range of input voltages was tested and was found to remain within ± 0.08 volts over a range of 6.00 volts to 2.80 volts. Below this, the power supply ceased to function and produced zero output. The effects of the trim circuit were also tested. With 5.00 volts input and full load output current, the output voltage can be adjusted from 11.93 volts at open circuit on the trim pin, through 12.00 volts at 22 K Ω , to 13.01 volts at 330 Ω .

After final assembly and checkouts, the camera was placed into actual service monitoring tests. The camera proved to be quite resistant to the environment and consistently provided a better picture than the other cameras being used. Most of the picture improvement is due to the use of the CCD image sensor rather than a vidicon tube. There was much less problem with "flares" at illumination highlights, no image "burn-in" or ghosting, better contrast, higher resolution, and capability of operation at low light levels. In one instance, no additional light was needed for a monitoring task in the dimly lit test facility.

The actual running time of the camera on a single charge of the battery pack is quite important. Also important is any deterioration of the video signal output as the battery charge is nearly expended. The battery pack has a 7 amp-hour rating and the input current to the DC-to-DC converter is less than one amp. The DC-to-DC power supply holds the output voltage steady to very low battery voltages and it supplies both the CCD camera module and the TX1 video transmitter. From this, one might expect about 7 hours of constant operation. In order to test this expectation, the camera was given a full charge from a commercial automated battery charger (Christy model CASP 2000H) and then was subjected to "burn-down" tests. For these tests, the camera was aimed at a video resolution test target, turned on, and set up with a video titler unit overlay displaying the elapsed time since turn-on. This output was recorded on a connected VCR unit so that any anomalies could be reviewed. These tests showed that the video camera had between five and eight hours of continuous operating time available on a single charge. This variation of operating time is probably due to incomplete charging of the battery pack because of internal problems in the automated battery charger.

V. RESULTS

The above tests show that this implementation is substantially correct but that a few changes are in order. One thing which is apparent is the unavoidable down time required to recharge the battery pack. Since, with this design the battery pack is built-in, that means testing must stop for that period unless another camera can be substituted. A better design would be to use a readily replaceable battery cassette. In this way, spare battery cassettes could be kept on charge and ready for instant substitution so there would be only a few minutes lost from the test schedule. In some tests, it is desirable to place a camera where a human operator would be, having the camera lens at the operator's eyepoint. This leads to a requirement for a shorter length case, and to the desirability of the selection of placement of the fiber-optic cable. For the most useful camera, the internal structure which secures the components should be increased in strength to best protect the components from damage.

The tests also show that the manually operated On/Off switch at the receiver and control station, while suitable for this experimental program, should be augmented with direct control from the test area control console. This will require a computer interface of either IEEE-488 or RS-232 protocol. The actual design of this controller set is beyond the scope of this present report and should be the subject of requirements generated by the testing. It is envisioned, however, that several cameras might be managed and their outputs integrated into a "mosaic" display. Some of this would be best done using commercial video surveillance equipment.

VI. CONCLUSIONS AND FUTURE PLANS

Overall, this unit was successful for its intended purpose, and would be a generally useful device with no changes. Since the start of the project, it was found that the Math Associates model XV-1050 fiber-optic video transmitter (TX1) is no longer available. Moreover, there are rather simple changes which would make the camera much more suitable for the intended purpose.

Figure 3 shows the design concept of a second-generation, fiber-optic video camera. The casework is revised substantially to provide for a removable battery cassette which screws onto the rear of the camera case. The configuration shown has this cassette comprising about one-third of the camera's length. If special requirements demand it, a shorter mushroom-shaped cassette could be designed, or even a near-zero length adapter to a cable leading to a remote battery, or possibly to a source of system power. This battery cassette would contact coaxial bullseye-pattern contact traces on the power input bulkhead via spring-finger wiping contacts. The I/O board and the power & distribution board perform essentially the same functions as before. They will be made using printed circuit

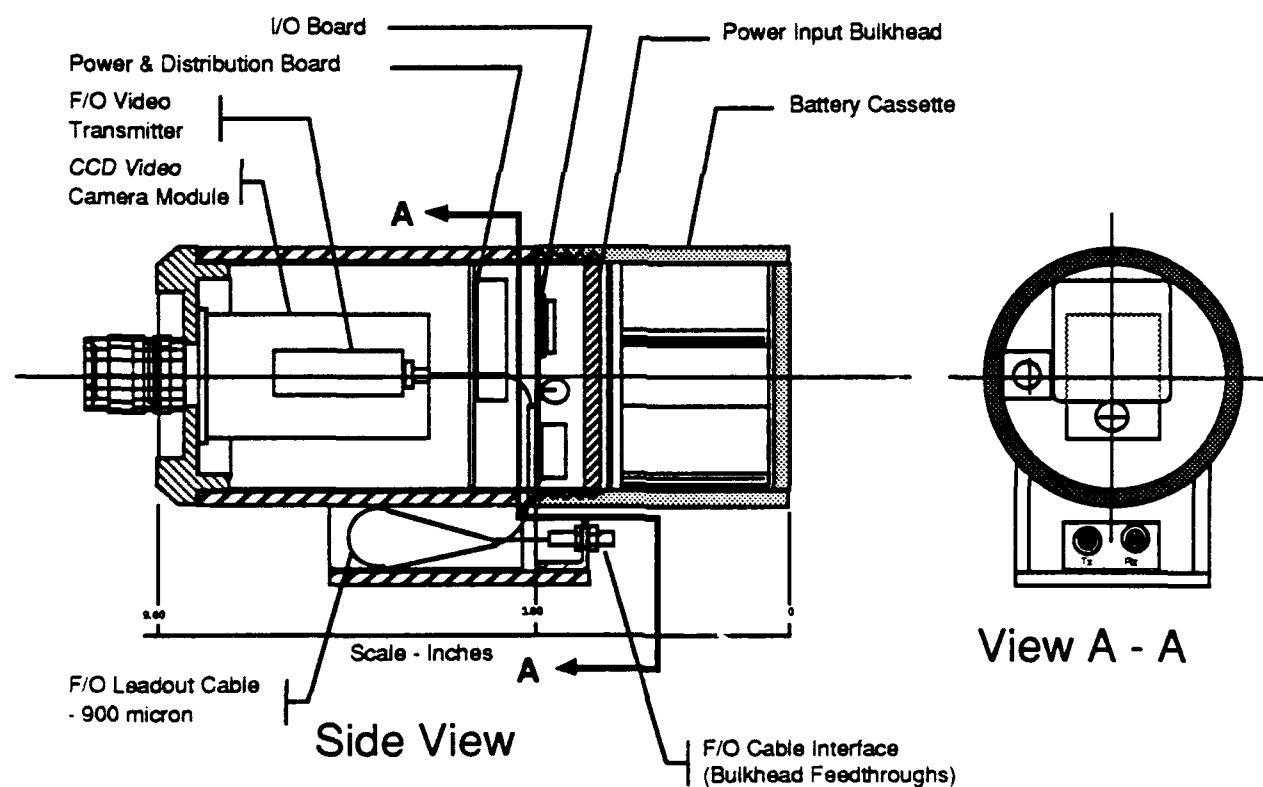


Figure 3. Revised video camera design.

techniques and the interconnections will be simplified and made more robust. The configuration management performed using JP1 and S2 would be replaced by a DIP switch mounted on the power input bulkhead and accessible when the battery cassette is removed. The function of S1 might be eliminated altogether by the use of a series MOS transistor which would control power to the DC-to-DC converter. Such switching would reduce the current drain to the microamp levels — low enough to be of no concern during active use of the camera.

As mentioned above, the TX1 fiber-optic video transmitter module is no longer available. Other sources were found of functionally similar units, but with different physical packaging. The one most promising for future use is the Optelecom Model No. 3151T — SMA. This unit measures 0.75 in. by 0.75 in. by 2.4 in. and is fitted with BNC video signal input and SMA fiber-optic output connectors. There is no convenient way to provide a wall feed-through using this unit. In addition, there is the desirability of variable positioning of the camera's fiber-optic interface to the cable. The concept shown uses a pair of 900 micron buffered fiber-optic cables as leadout jumpers. These cables have a buffer layer instead of a full plastic jacket to protect the optic fiber and cladding. These leadout cables would connect to the RX1 and TX1 internal to the case and would be routed through a narrow slot (about one millimeter wide) through the wall of the case at the base of the threads where the battery cassette attaches. A short service loop is taken in the hollow mounting foot and the leadout cables are terminated into SMA bulkhead feedthroughs mounted on an L-bracket. This bracket is secured by screws and may be positioned with the fiber-optic interface either to rear, left, right, or down by hole selection.

The experimental version of this camera has proven to have substantial advantages over the previously used cameras. Since there are no commercial units which fulfill all of the requirements, it is appropriate to extend the experimental design along the lines of the above description. In this way, the monitoring of tests can be accomplished with greater efficiency while yielding superior images.

APPENDIX

APPENDIX

This appendix contains the parts list, shop drawings, and other documentation which was used to produce the parts needed for this project. These drawings are substantially correct, but some variation may have occurred between the details of the drawings and the final part actually used. Any variation would have been to accommodate available materials, to provide better interfacing between parts or, as in the case of the Rear Bulkhead, there is only a blank part produced. For the Rear Bulkhead, the hole pattern needed had to wait for the final parts placement and was done as a hand-fit action. Other parts such as internal support brackets were hand made as required and were not documented since this is a one-off experimental and evaluation unit.

PARTS LIST

R1 2.2 Meg Ω , 1/4 watt carbon film
R2 1500 Ω , 1/4 watt carbon film
R3 100 K Ω , cermet trimpot

C1, C2 .. 47 μ Fd, 35 volt tantalum
C3 0.1 μ Fd, 350 volt ceramic

L1 40 μ Hy, 0.070 Ω inductor - PICO # 42345
L2 40 μ Hy, 0.141 Ω inductor - PICO # 41260

CR1 1N4148, signal diode

VR1 1N4734, zener diode $V_z = 5.6$ volts

RX1 Fiber-optic (SMA) interfaced PIN photodiode, Hewlett-Packard # HFBR-2208

TX1 Fiber-optic (SMA) video transmitter module, Math Associates # XV-1050

U1 CD4093B, Quad CMOS NAND gate, Schmitt-trigger

U2 DC-to-DC converter module, 5 to 15 volts in, 12 volts out, PICO # LRE12S

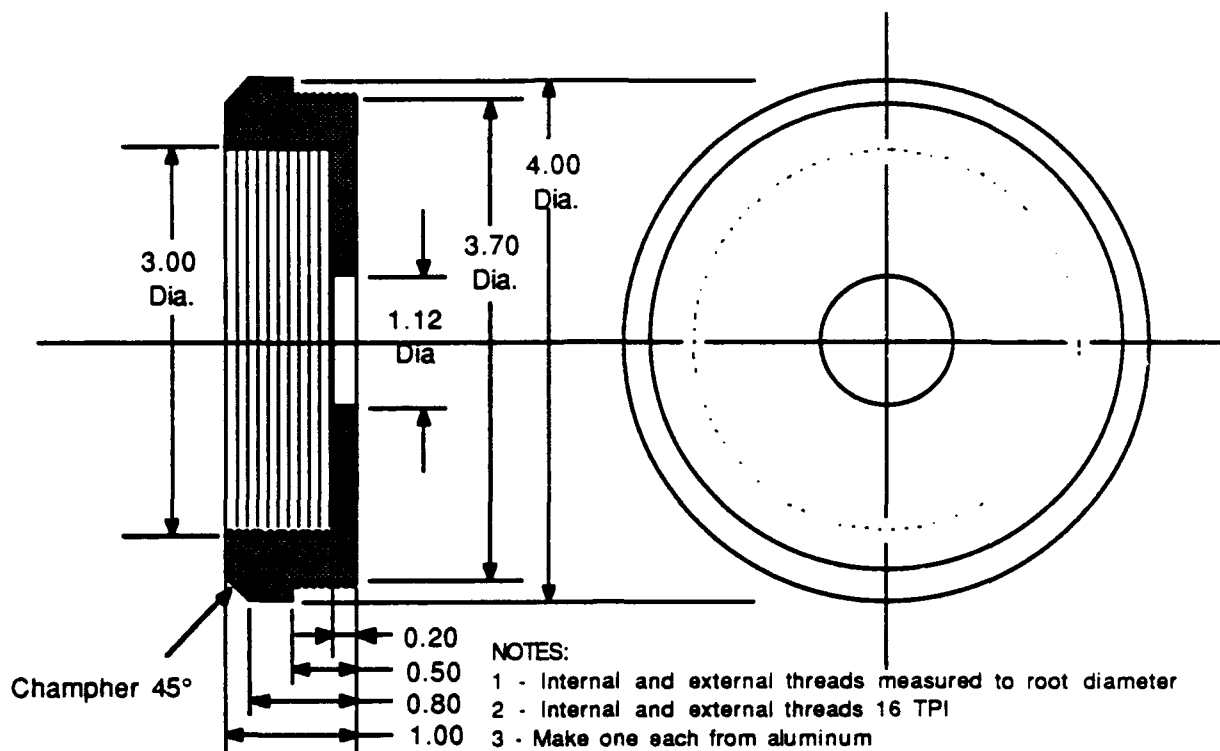


Figure A1. Forward bezel: shielded video camera (F/O video 101).

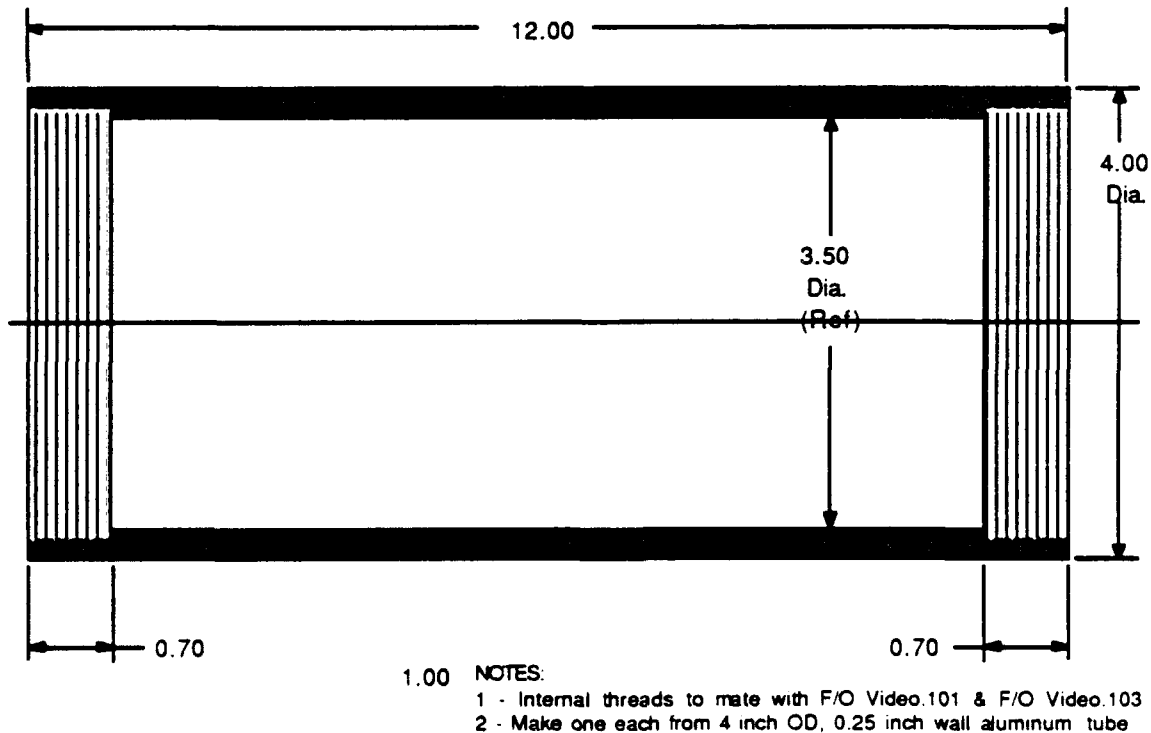


Figure A2. Case body: shielded video camera (F/O video 102).

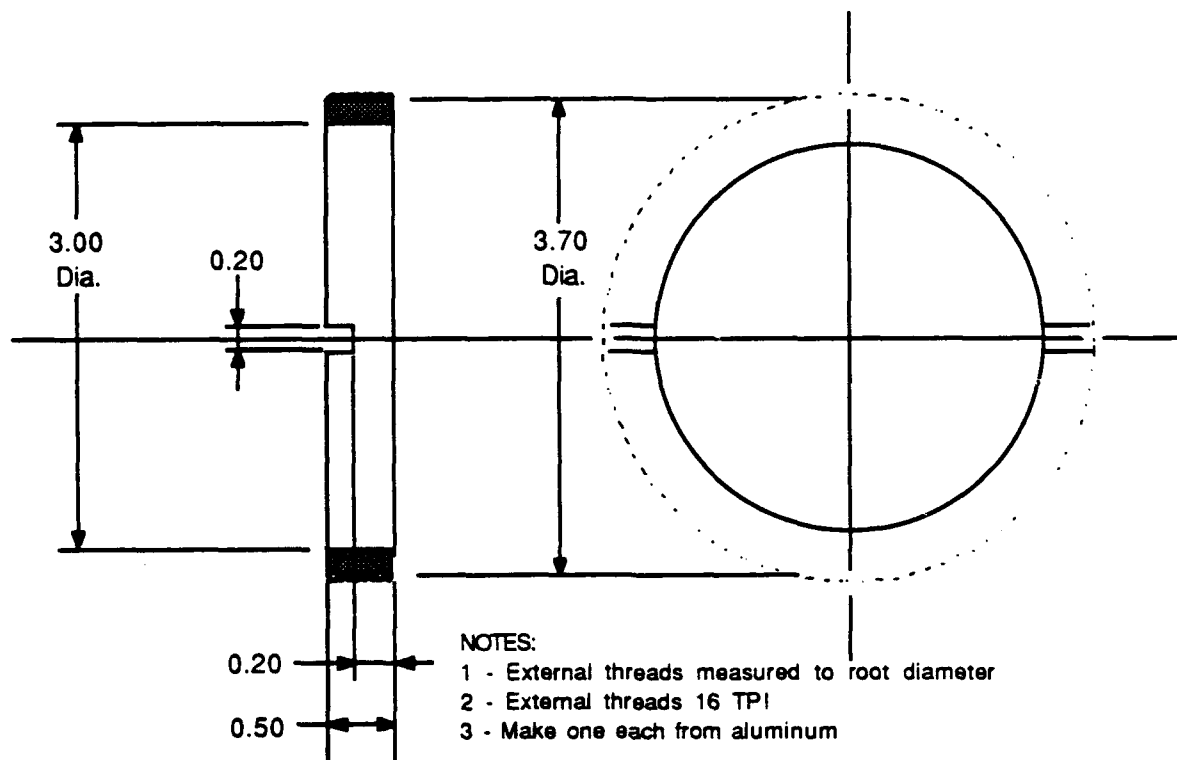
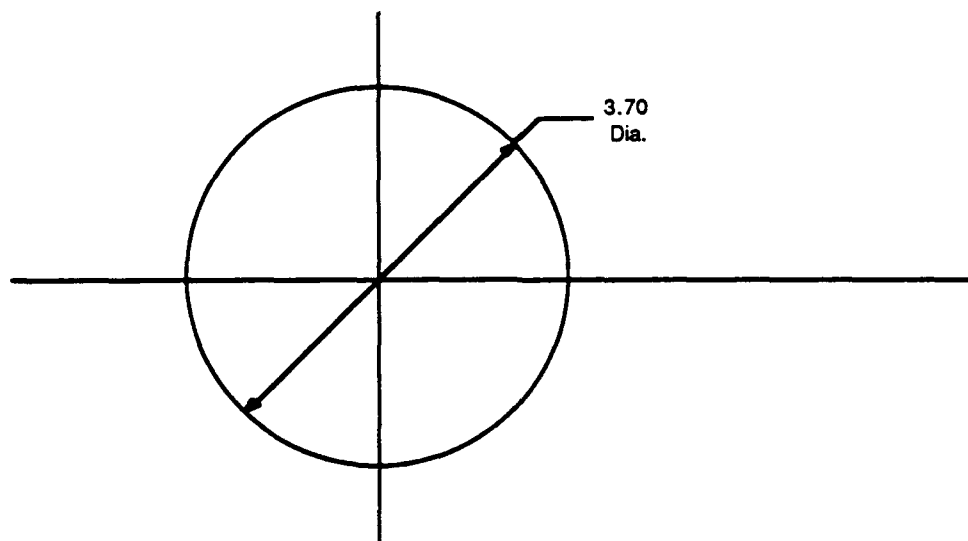


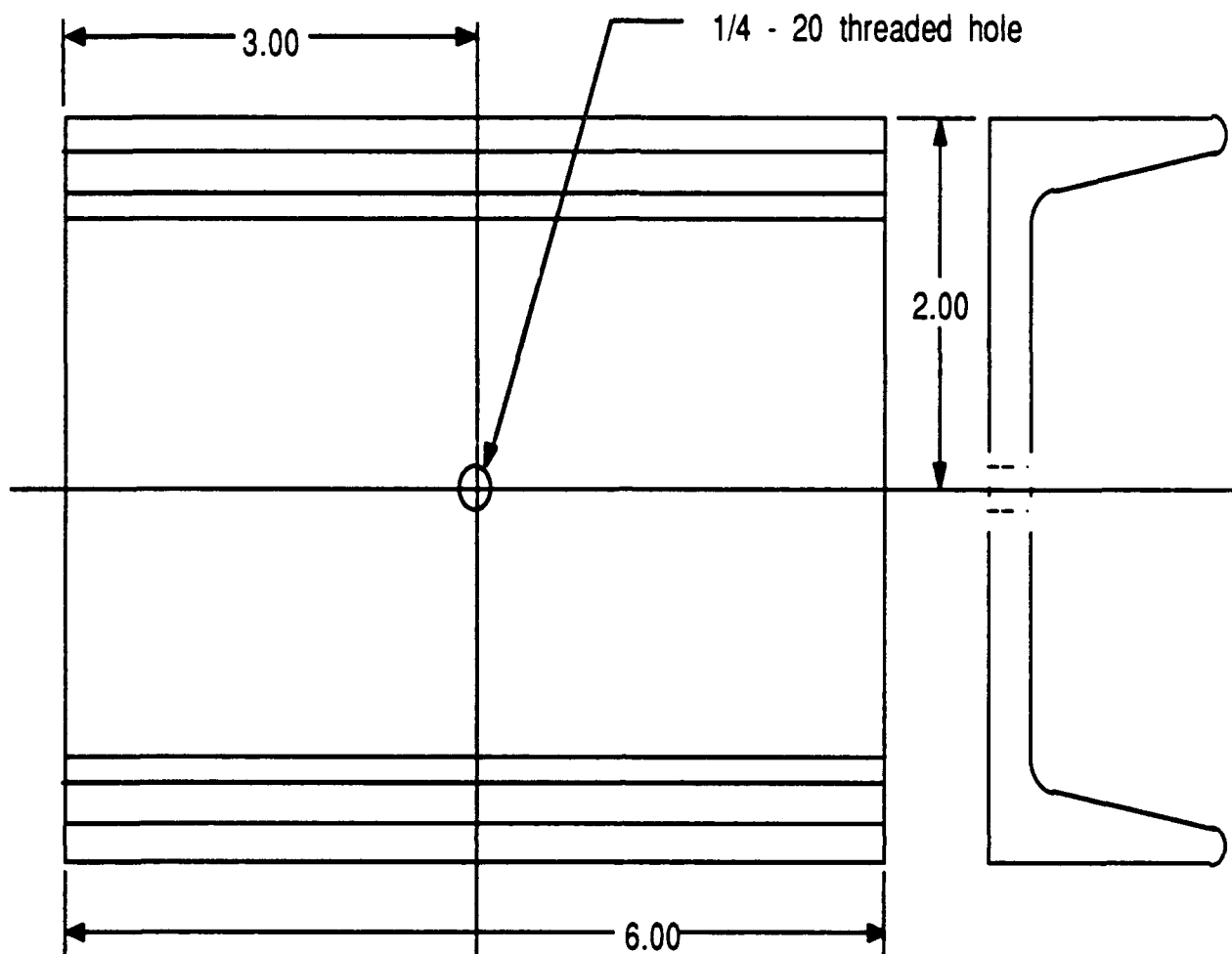
Figure A3. Rear securing rings: shielded video camera (F/O video 103).



NOTES:

- 1 - Make one each from aluminum plate appx. 0.0625 inch thick

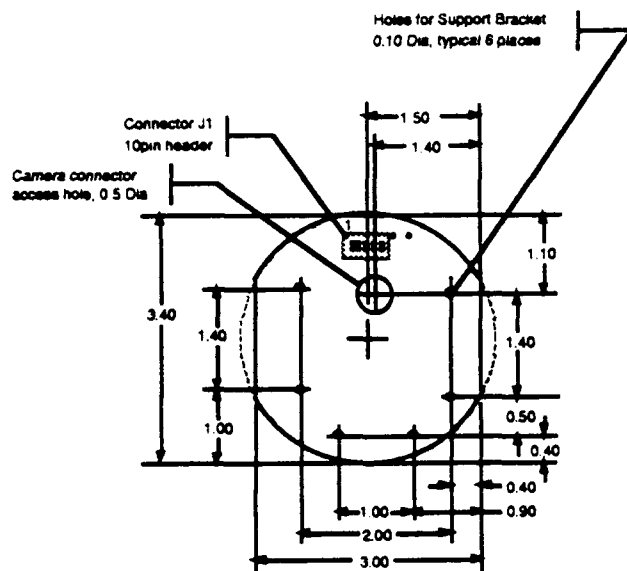
Figure A4. Rear bulkhead: shielded video camera (F/O video 104).



NOTES:

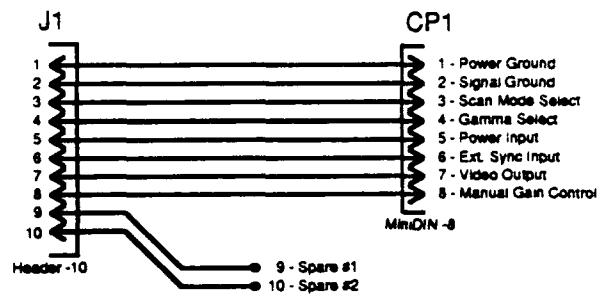
1 - Make one each from 4 x 1.75 inch aluminum channel

Figure A5. Mounting foot: shielded video camera (F/O video 105).



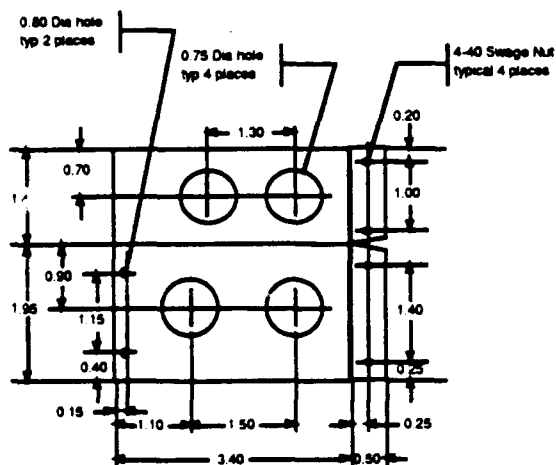
Bulkhead #1 Layout

Quan: 1 each
Matl: Fiberglass periboard 0.064" thick



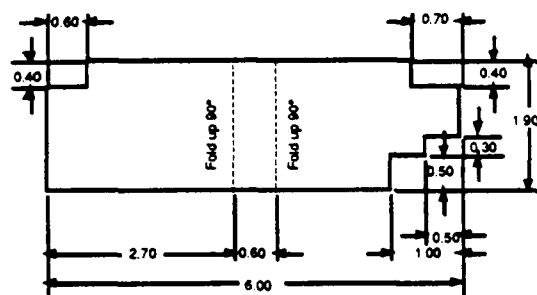
Bulkhead #1 Wiring

Figure A6. Bulkhead # 1: CCD camera.



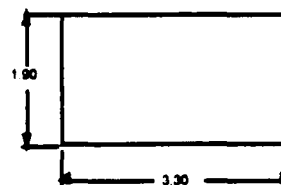
Support Bracket

Quan: 2 each
Matl: Aluminum 0.020" thick



Inner Insulator

Quan: 1 each
Matl: Mylar 0.005" thick



Circuit Board Insulator

Quan: 2 each
Matl: Mylar 0.005" thick

Figure A7. CCD module bracket/insulators.

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